NASA Technical Memorandum 89606

Life Sciences Space Station Planning Document: A Reference Payload for the Exobiology Research Facilities

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NASA Office of Space Science and Applications
Washington, D.C.

National Aeronautics
and Space Administration

Scientific and Technical
Information Branch

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FOREWORD

NASA's Exobiology Program is directed toward understanding the origin, evolution, and distribution of life and life-related molecules throughout the universe. The unifying concept underlying research in exobiology is that the origin and evolution of life is an integral part of the origin and evolution of stars and planets; thus, life is a product of a continuum of physical and chemical processes that started with the origin of the universe itself. Constructing a plausible pathway that leads from the origin of the universe to the establishment of a sustained biota on Earth involves the synthesis of data collected from ground-based, space and planetary investigations. In this context, the Space Station will contribute significantly, providing three new tools: enhanced observational capability; *in situ* cosmic dust collection; and a unique environment for a variety of simulations.

This document specifically addresses two research facilities on the Space Station which will serve the interests of Exobiology. The two facilities are the Gas Grain Simulation Facility and the Cosmic Dust Collection Facility. The former will be located within the pressurized research laboratory and the latter will be an attached payload. A unique aspect of these facilities is that they will be shared by Planetary Science and, in the case of the Gas Grain Simulation Facility, will also serve the interests of Astrophysics.

Research conducted in the two facilities will uniquely address fundamental questions in Exobiology, Planetary Science, and Astrophysics and will contribute immensely to our understanding of the formation of planets and the evolution of life.

This document provides the range and scope of typical experiments which could be performed in the two facilities, identifies representative experiments, and defines attendant hardware and resource requirements.

INTRODUCTION

The Cosmic Dust Collection and Gas Grain Simulation Facilities represent collaborative efforts between the Life Sciences and Solar System Exploration Divisions designed to strengthen a natural Exobiology/Planetary Sciences connection. The Cosmic Dust Collection Facility is a Planetary Science facility, with Exobiology a primary user. Conversely, the Gas Grain Facility is an Exobiology facility, with Planetary Science a primary user.

Requirements for the construction and operation of the two facilities, contained herein, were developed through joint workshops between the two disciplines, as were representative experiments comprising the reference payloads. In the case of the Gas Grain Simulation Facility, the Astrophysics Division is an additional potential user, having participated in the workshop to select experiments and define requirements.

This document was compiled by an Exobiology/Planetary Science working group and describes reference payloads for each facility based on overall science objectives, representative experiments, and equipment. The reference payloads <u>do not represent the outcome of a payload selection process</u>.

PURPOSE

The purpose of this document is to develop a reference payload for research that would be conducted in the Gas Grain Simulation and Cosmic Dust Collection Facilities, and to define the engineering requirements (mass, power, volume, etc.). The document details the evolutionary process from science goals and objectives through experiments and hardware and resource requirements. Requirements validated by this document are described in Missions 308 and 112 of the Mission Requirements Data Base.

This document is one of a series which will address the design of and the scientific rationale for certain typical experiments that might be conducted in the two facilities. This information serves to ensure that Space Station designers and equipment specifiers are responsive to their users, the science community. No experiments have yet been selected for flight.

Table 1 summarizes the engineering requirements for each of the facilities and compares them to the engineering envelope detailed in the Mission Requirements Data Base.

	Gas/Grain Simulation Facility			Cosmic Dust Collection Facility		
	Mass	Volume	Power	Mass	Volume	Power
Mission Requirements Data Base	200 kg	4.0 m^3	2.0 kw	1600 kg	27 m^3	1.2 kw
Reference Payload	180 kg	3.2 m^3	1.54 kw	1600 kg	27 m^3	1.2 kw

Table 1. Engineering Envelope Summary

BACKGROUND

The process of requirements and experiment definition began with two major workshops. The first addressed the Gas Grain Simulation Facility and was held at NASA's Ames Research Center on August 22-24, 1985. The second dealt with the Cosmic Dust Collection Facility and was held at the Lunar and Planetary Institute, in Houston, Texas, on December 16-18, 1985. Participating in these workshops were scientists representing all interested research disciplines. Results of the two workshops are presented in references 1 and 2. In summary, they strongly endorsed the two facilities, outlined construction requirements and engineering specifications, and developed ranges of research efforts which could be carried out in the facilities.

Following the initial workshops, studies were initiated and working groups convened to prioritize science objectives and develop engineering designs. In the case of the Gas Grain Simulation Facility, this effort (whose results are presented in the following sections) led to a modification of the scope outlined in the original workshop. Specifically, two broad classes of experiments were initially defined: particle experiments involving one or a few particles, and cloud experiments involving a large number of particles. However, further study of the latter class of experiments revealed a number of limiting factors which cannot be satisfactorily resolved in the IOC time frame. These are: experimental difficulties in maintaining clouds of particles even in microgravity, due to electrostatic effects, coalescence of the cloud by the levitation mechanism, and wall effects; significant increase required in technical capabilities of the facility and data handling equipment; and a prohibitive increase in crew time requirements. It was, therefore, decided to focus on individual particle experiments and interactions for the Gas Grain Simulation Facility at IOC. This descoping will not compromise science returns, since many of the important science questions outlined in the original workshop can be fully addressed by single-particle experiments. Expansion of the facility to allow cloud experiments could be a part of the FOC-and-beyond capability.

SCOPE

This document contains two chapters, arranged identically, one for each facility. The first section of a chapter is an introduction outlining science objectives and describing the facility. It is followed by a section detailing the scientific rationale for the experiments. The third section is a descriptive list of the representative experiments. Fourth is the section detailing a typical 90-day scenario for a selected experiment. It is followed by a section that lists projected supporting equipment and engineering specifications. Next comes a copy of each of the two missions as described in the Mission Requirements Data Base. At the end of the document is a list of the participants in the workshops and the contributors to this document, and the references used to compile this document.

CHAPTER 1

GAS GRAIN SIMULATION

FACILITY

INTRODUCTION

The overall objective of the Gas Grain Simulation Facility for Exobiology is to study the formation, growth, and accretion of dust grains and their interactions with interstellar gases in space-based simulations in order to trace the history of organic matter in the primitive solar system; and to evaluate the significance of biologically produced organic matter in the evolution of the terrestrial planets.

Planetary Sciences is concerned with both the cosmological processes that led to the formation of the solar planets (and planetary systems in general), and the behavior of geological and atmospheric materials within existing evolved planetary bodies. More specifically, the research interest centers around the behavior and interaction of particulate materials that have free paths which are distant from the influence of a solid or liquid surface.

The research goals of the two disciplines share the common requirement of study of particles in an extremely low-gravity environment since, in general, they require particles to be suspended for periods substantially longer than is practical at 1-g. This commonality led to the concept of a shared gas grain simulation facility. The facility requires approximately $3.5 m^3$ of space (about two racks) in a Space Station research module. It comprises an adaptable particle suspension chamber in which experiments are conducted, support equipment (control, measurement, electronics), and stowage area. The chamber is $.01 m^3$ in volume, with a fairly sophisticated environment control system capable of controlling internal gas composition, pressure, and temperature. Required g levels are approximately 10^{-5}-g for most experiments.

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Interactions between a gas phase and a solid phase include sorption phenomena, heterogeneous catalysis, and many other familiar terrestrial physical-chemical processes. Such interactions are important in space, particularly for their roles in the cosmic history of the biogenic elements and compounds. Elucidation of this history involves: 1) tracing the physical and chemical pathways taken by the biogenic elements and compounds from their origins in stars to their incorporation in planetesimals; 2) measuring the biogenic elements and compounds in the solar system and galaxy to develop theories about the formation of the solar system; and 3) determining how the physical and chemical properties of the biogenic elements and compounds influenced the formation of the solar system and the bodies within it. In this context, interactions among gases and grains in space are fundamental to theories of the origins of the constituents of interstellar clouds, comets, meteorites, interplanetary dust, and solar system bodies. Experiments capable of yielding insight into the nature of these processes are thus of great value in confirming or refuting various aspects of these theories.

Grain Nucleation

Nucleation, condensation, and growth of carbonaceous particles must occur in the envelopes of carbon stars to yield the observable circumstellar dust and molecules. Similar processes are thought to occur under conditions as diverse as those in interstellar clouds and the atmospheres of the outer planets and their satellites; observational evidence suggests the presence of fine-grained dust (from less than 0.1 micron to about 1 micron in diameter, presumably containing varying proportions of hydrogen, carbon, nitrogen, and oxygen) in both types of environments. Although there are some theoretical discussions of the properties of dust based on remote spectrophotometric observations, the physical and chemical characters of the materials remain poorly understood, as does the nature of the processes that produced them.

Although theories of grain nucleation, condensation, and dust growth are being developed, the complexities of the natural processes make them difficult to model. The few experimental studies that have been conducted were performed under conditions that do not permit scaling to relevant astrophysical environments. A common feature of the processes in the environments mentioned above is that grains form and evolve over substantial lengths of time while suspended in a thin gas phase, largely -- if not entirely -- independent of other grains. This condition should influence the rate of formation, chemistry, structure, morphology, and other characteristics of the dust. While this condition is difficult, if not impossible, to model in a terrestrial laboratory, it may be effectively simulated in microgravity. Experiments in Earth orbit would provide "space truth" for analogous experiments carried out in terrestrial laboratories on computers. Furthermore, they would yield samples under well-defined conditions, whose properties could be readily determined and compared with those of natural material either remotely sensed or obtained from meteorites, interplanetary dust, and dust returned from a comet.

Grain Accretion

Once grains are formed in the solar nebula, they must accrete to form the larger planetesimal-sized objects thought to have been the building blocks of planets. The rate and mechanism for planetesimal formation are believed to depend on the size, distribution, composition, and structure of nebular dust. In theory, the ability of colliding grains to cohere depends largely on short-range Van der Waals interactions, although electrostatic and ferromagnetic forces may come into play. It has been suggested that grains endowed with mantles containing organic matter and/or icy components should accrete and grow faster than others. Despite its implications for early solar system history, this suggestion has never been tested experimentally. Microgravity facilities would provide excellent opportunities for model studies of grain accretion in the space environment.

Gas-Grain Reactions

In addition to growing by the passive accretion of gaseous species to its surface, a dust grain can provide an active surface to catalyze reactions of species sorbed to it, or can itself be changed by chemical reactions with sorbed gases. Chemical reactions between gas and dust hypothesized to occur in interstellar clouds and in the solar nebula may account for organic matter observed by radio astronomers in the clouds, and by chemists in meteorities, comets, and interplanetary dust. These ideas are most commonly expressed in terms of a Fischer-Tropsch Type (FTT) synthesis in which the surfaces of silicate, metal, or metal oxide grains suspended in interstellar clouds or the solar nebula provide active sites for catalysis. Molecules of hydrogen (H_2), carbon monoxide (CO), carbon dioxide (CO_2), and ammonia (NH_3) sorbed on the sites at temperatures from 300^0 to 600^0 K are thought to have been converted spontaneously to organic compounds and other carbonaceous phases. These products, in the case of the solar nebula, were subsequently retained on the grains and accreted into primitive planetesimals. According to the FTT synthesis scenario, interstellar molecules represent products of nebular synthesis that were ejected into the surrounding medium during dissipation of prestellar nebulae.

Recent data from analyses of organic matter in meteorites and from laboratory FTT syntheses suggest, however, that FTT processes cannot explain all the observed molecular and isotopic characteristics of the natural products. What they can account for remains to be clearly established, and additional artificial syntheses may provide the clues, provided they are conducted under conditions that may be extrapolated to natural processes.

All laboratory FTT reactions have been conducted at or near 1 atmosphere (atm) total pressure with a bed of catalysts. Under these conditions, grains collide, other, chemical intermediates can migrate from catalyst sites on one grain to those on others, and opportunities exist for a diverse chemistry. In the nebular environment, the total pressure is 10^{-3} to 10^{-6} atm and dust is expected to comprise about 1% of the mass. Under these conditions, sorbed gases and reactive intermediates produced on a grain would remain on that grain (or desorb into the gas phase where other processes would govern their fate) until the grain is accreted with others into larger objects; consequently, the composition and abundance of the products and the rates at which they could form may be strongly constrained and different from those observed in terrestrial laboratories. Gas-grain interactions that are independent of a bulk solid phase should be amenable to study under microgravity conditions.

EXPERIMENT DESCRIPTIONS

Discipline: Exobiology

Session Title: Titan Atmospheric Aerosol Simulation

Objective: The objective of this experiment is to simulate the formation of the high altitude organic haze on Titan. This experiment would build on the extensive experience already obtained in ground-based laboratories in simulating organic material production in Titan-like atmospheres. The microgravity environment would allow for the extension of these ground-based experiments. Specifically, the formation of organic particles -- the nature of their growth (coagulation vs. condensation), their optical scattering and physical properties -- can be investigated. This experiment is timely because of the upcoming Cassini Mission to Titan.

Performance Requirements:

1. Type/number of specimens: one Titan haze particle grown in the chamber.
2. Measurements/samples: optical data obtained during the experiment.

Discipline: Planetary

Session Title: Particles in the Solar Nebula

Objective: The objective of this experiment is to simulate the growth of inorganic refractory particles as thought to occur in the early phase of the solar nebula. The growth by coagulation is not understood. Evaporation of refractory materials into a low pressure environment that has a carefully controlled temperature gradient will produce refractory smokes when the "critical supersaturation" of the system has been exceeded. Measurement via light scattering or extinction of the point at which nucleation occurs cannot only yield nucleation data, but if optical monitoring is continued, will also yield data on the sticking coefficients of newly condensed submicron refractory particles by determining the time evolution of the particle size distribution. Optical methods should be supplemented by active particle collection (and subsequent analysis) in order to determine the morphology and degree of crystallinity of such newly formed particles.

Discipline: Astrophysics/Exobiology

Session Title: Carbon Grain Formation in Stellar Atmosphere

Objective: The objective of this experiment is to simulate the formation of carbon particles in the atmospheres of late-type stars. The dust condensation process is not understood. All models fail to describe this process by several orders of magnitude, yet it is from this dust that an important component of the solar system has formed. This experiment would be based on our observation of dust formation in these objects and laboratory studies of particles suspended in cryogenic rare gas solids. The microgravity environment would allow us to follow the growth of a particle from its free molecular through molecular cluster to particle form. To date, all terrestrial experiments have failed to mimic these conditions because of gravitational effects. The nature of their growth, optical scattering, and physical properties can be investigated in a way similar to that described in #1 above.

Performance Requirements:

Similar to #1 above, this time, however, using C_2H_2 (acetylene) instead of CH_4 (methane) as the initial gas.

Discipline: Planetary Science

Session Title: Rebound Effects and Coagulation in Particle-Particle Interactions

Objective: The objective of this experiment is to simulate coagulation of aerosols during particle-particle collisions. The experiment is relevant to a wide variety of disciplines. Experiments of this nature can be performed that cover a wide range of particle types and collision velocities. Possible individual experiments include:

a. Low velocity collisions between fragile particles. This is relevant to the formation of grains in the early solar nebula.

b. Collisions between ice particles. This is relevant to determining viscosity, wave dispersion, and coefficient of restitution in planetary rings.

c. Collisions between liquid drops where coalescence, rebound, coagulation, drop breakup, and development of the size distribution during drop breakup are studied. This is relevant to cloud formation processes.

Performance Requirements:

1. Type/number of specimens: 3 types -- dust grains, ice particles, liquid drops. A wide range of potential compositions are possible.
2. Measurements: High speed photography, charge measuring capability, optical light scattering measurements.

GAS GRAIN SIMULATION FACILITY
TYPICAL 90-DAY SCENARIO

90-Day Timeline for Titan Atmospheric Aerosol Simulation

Weeks 1-5. Deployment: The gas grain simulation facility is stowed, its volume in stowage is essentially the same as its deployed volume (4 cubic meters). Deployment consists of releasing launch-safety control valves on the gas canisters and power supplies, interfacing data systems connecting the power system to Station utilities, and following a set of preprogrammed turn-on prompts from the GGSF computer. This is a simple connection process and only requires about 1 hour. The 5-week period is allocated to allow for scheduling.

Week 6. During week 6 the system would start itself based on commands from ground.

DATA AND COMMAND SYSTEM

The data and command system we envision is as follows. The facility would have a built-in computer control/command system. This system would control all operations of the facility during an experiment and would involve fair degree of automonous decision making. It would monitor system engineering status and select the relevant information packet and send it to the Station data bus for forwarding to ground operations. The operations team on the ground would review the downlink data and transmit commands to execute preprogrammed sequences or to enter a new program sequence. During an experiment data summaries would also be sent down to ground control. The data exchange requirements are modest, probably amounting to less than 1 kilobyte/day. Data/command uplinks would probably occur about twice per week. In addition to telemetry data, all the raw data and engineering system information would be recorded on a tape recorder with the GGSF for later retrieval. By using AI techniques on the onboard controller and by allowing for a system that can be controlled by commands from the ground we have virtually eliminated crew time rquirements for the operation of the experiment. The controller would allow watch for faults and would automatically shut down the system in the event of a serious problem.

Based on the controller checkout of the system, the ground sends up the command to start the facility and begin pump-down and calibration. Steps might include:

1. Evacuate chamber, test vacuum and gas handling system. Two unresolved issues here are:
   a. Disposal of waste gas (venting or storing).
   b. Safety concerns with the gas mixture for this experiment (3% methane and 97% nitrogen). It is not considered flammable on Earth.
2. Run calibration tests. Calibration tests for this experiment involve testing the laser light source and the optical sensors. This may be accomplished by introducing a latex sphere of precisely known size and optical properties into the chamber and activating the acoustic levitation mechanism. Then the laser light would be activated and scattered light from the sphere measured. This would allow for checkout and calibration.
3. These calibration data sent to ground.
4. Data are processed.
5. Commands sent up to begin the experiment. Because commands and data are not relayed in real time this procedure takes a week to accomplish.

<u>Week 7</u>. Begin gas fill with 3% methane, 97% nitrogen mixture. Set the chamber pressure to about 0.2 mb and allow to equilibrate. Data is obtained to get the baseline light scattering due to the particle-free gas (Rayleigh scattering). This data is recorded and summary data sent to ground. Commands are then sent to activate the energy source.

<u>Weeks 8-11</u>. The energy source which will cause reactions in the methane-nitrogen mixture can be either a 100 watt ultraviolet light source or a 200 V DC source driven by a 15 ma supply (e.g., Khare et al., 1985). The levitation mechanism is activated. At this stage an optical levitation scheme

to hold the vary small (nanometer) grains that form in the reaction probably would be most appropriate. These grains will collect in the center of the levitation well and eventually coagulate into one particle of larger size. Particle size, shape and optical properties are monitored by the optical sensors, which detect light scattered over all directions (all 4 pi seradians). When the size of the particle is too large for optical suspension, then on command from the ground or based on onboard decisions, acoustic levitation is activated. The experiment is operated in this mode for 3 weeks as the particle grows.

Week 12. The particle is removed (electrostatically) from the changer and stored (negligible voume required) for retrieval along with the data tape of the full experimental and engineering data. The remaining gas is either vented or compressed for transport to Earth.

SPECIFICATIONS ON VOLUME, MASS, POWER AND CREW TIME

Property	New Value	Rationale
Volume	3.2 m^3	Total sum of equipment volume
Mass	180 kg	Descope to do particle experiments only (not cloud experiments)
Power	1540 watts	Trading off low power requirements with longer duration of each experiment
Crew time/90 days	5 hours setup 0.5 hours/week	Simpler single particle experiments and a smart controller allow significant reduction in crew requirements
Communications	Ground to experiments Data and commands	To interface with experiment controller
Data rate	Less kilobyte/day	Built-in tape recorder
Changeout	Tape recorder Single particle sample	

REFERENCE PAYLOAD
GAS GRAIN SIMULATION FACILITY

Equipment	Dimensions (in cubic meters)	Mass (in kg)	Power (in watts)
Laser light source	.4572	20.00	150
Optical fiber light sensor	.0508	.20	10
Solid state light sensor	.0635	.50	20
Laser levitation light sensor	.0838	2.50	10
Acoustic resonator	.2769	8.00	100
Temperature controller with heater	.6096	.50	200
DC excitation power supply	.4572	20.00	200
UV light sources	.2070	2.50	250
Central data processor/command system	.2870	35.00	100
Recording equipment	.2286	1.00	100
Experimental chamber	.0100	10.00	400
Chamber accessories	.5000	80.00	

- Performance time: essentially run continuously under the control of self-contained electronics

- Frequency: ??

- Step functions: ??

- Specimens/samples: only samples are the tape from the tape recorder and the small single-particle container

- Core/investigation: ??

- Sample disposition: return to Earth

Resources: See above

Trash:

- Volume: The actual chamber size is about 10 cm on a side, the total waste gas from the titan experiment would be 1000 cc of gas at 0.2 mb or about 2 cc of gas at STP. Not much. Total mass of this gas is 2 milligrams. The gas is typically 3% methane and 97% nitrogen. There might also be experiments in which the entire volume of gas is pure hydrogen.

Logistics/Resupply: see above

Data system: see above

Video: probably not applicable

MISSION REQUIREMENTS DATA BASE

SAAX308

****
Entries in this data base are to be used only as a source of illustrative detail about the intended uses of the Space Station complex. The data base by itself cannot be used to infer an aggregate performance envelope.
****

NAME

Payload element name	Gas/Grain Simulation Facility
Last update	100186
Country of origin	USA NASA OSSA (SAAX)
Contact	L. Chambers, Code EB, NASA HQ J. Campbell, Code EL, NASA HQ
Phone number	(202) 453-1525/1608
Status	Planned

FLIGHTS

Flight Schedule

Flight Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Equipment up	1	2	2	2	2	2	0	0	0	0
Equipment down	0	2	2	2	2	2	1	0	0	0
Operational days	0	0	0	0	0	0	0	0	0	0
OTV flights	0	0	0	0	0	0	0	0	0	0
Early flights	0	0	0	0	0	0	0	0	0	0
Late return										

Objective

Study the interactions-chemical and physical-among particles and gases in order to examine and quantify the conditions of origin and evolution of biogenic elements and compounds and of grains and aggregates of silicates, oxides, and other minerals which now comprise the solar system. The data would increase our understanding of the origin of small bodies (comets, asteroids, protoplanets), the formation and evolution of biogenic materials (especially effects of catalysis), and particle dynamics.

Description

The facility is a chamber in which experiments are conducted, support equipment (control, measurement, electronics), and storage space. In general the experiments involve placing grains or aggregates into the chamber with various gases under various temperatures and pressures. The physical (aggregation/disruption, condensation/evaporation) and chemical changes would be monitored (optional/spectral observation) as a function of time. Sample would be recovered for chemical and petrologic analysis, and video and digital data would record the experiment. Particles and aggregates of ices, dust, and liquids would be starting materials. Experiments would include nucleation from the vapor, grain aggregation, gas-grain reaction, and disaggregation by low velocity projectile or by gas flow. The chamber and support hardware would remain on-station for several years. Experiment specific hardware would be changed out as needed, nominal once every six months. Most experiments can be operated remotely.

Type/Scale

Type Number	2
Importance of Space Station	9
Non-servicing DWV flights (per year)	0
Add Resources	Yes
Resource Reference	SAAX308

Orbit

Any Orbit

Special Considerations (Orbit):

Pointing/Orientation

Any Point

Special Consideration (Pointing/Orientation):

Power SAAX308

*AC

Operating (KW)	Nominal	2.00
Hours Per Day (Operating)		24.00
Voltage	Nominal	110.00
Frequency (HZ)		60.00
Peak (KW)	Nominal	20.00
Hours Per Day (Peak)		0.10
Standby Power (KW) (Non Operational Periods)		0.50

*DC

Operating (KW)	Nominal	1.00
Hours Per Day (Operating)		24.00
Voltage	Nominal	28.00
Peak (KW)	Nominal	5.00
Hours Per Day (Peak)		0.10
Standby Power (KW) (Non Operational Periods)		0.50

Special Considerations (Power):

Low voltage, high current power is needed for heaters. Various optical detectors and data acquisition systems will run for 2-10 hours. Peaks are associated with lamps, lasers, or high speed camera; duration is seconds to minutes.

Thermal

*Active

Temperature, Deg C	Operational	Min	0.00	Max	40.00
	Non-Operational	Min	100.00	Max	100.00
Heat Rejection, KW	Operational	Min	3.00	Max	25.00
	Non-Operational	Min	0.50	Max	0.50

*Passive

Temperature, Deg C	Operational	Min	-0.00	Max	-0.00
	Non-Operational	Min	-0.00	Max	-0.00
Heat Rejection, KW	Operational	Min	-0.00	Max	-0.00
	Non-Operational	Min	-0.00	Max	-0.00

Special Considerations (Thermal):

Conditions inside the chamber include volumes at temperatures as low as 4K and as high as 2500K. In all cases observation and data system will need to be maintained within +/-20 degree C of room temperature. Max heat rejection of 25KW is for minutes or less.

Data/Communications

Onboard data processing required Yes

Description:

Video, data, and experiment conditions need to be recorded and/or trans.

Onboard storage (MBIT)

Station data required:

Accelerations information in 3-dimensional space.

Communication Links:

From: Station To: Ground		Digital Data	Video Data	Voice
A. Generation Rate	(KBPS)	1.00	1.00	
B. Duration	(Hours)	1.00	1.00	0.50
C. Frequency	(Per Day)	24.00	24.00	1.00
D. Delivery Time	(Hours)	1.00	1.00	0.00
E. Security	(Yes/No)	No	No	No
F. Reliability	(%)	90.00	90.00	90.00
G. Interactive	(Yes/No)	No	No	Yes

From: Ground To: Station		Digital Data	Video Data	Voice
A. Generation Rate	(KBPS)	1.00	0.00	NA
B. Duration	(Hours)	0.25	0.00	0.50
C. Frequency	(Per Day)	1.00	0.00	1.00
D. Delivery Time	(Hours)	1.00	0.00	0.00
E. Security	(Yes/No)	No	No	No
F. Reliability	(%)	90.00	0.00	90.00
G. Interactive	(Yes/No)	No	No	Yes

Comment (Data/Communications):

Remote operation of some experiments is possible and desirable, but will require the continuous transmission of video and digital data while the experiment is operating (several days at a time). Crew interaction and recording can be used to reduce the need for continuous data transmission.

Equipment

Pressurized module code 1

Shared facilities

Equipment location legend

1. Internal/pressurized
2. External/attached/pressurized
3. External/attached/unpressurized
4. Free flyer (remote)

Equipment Location	1	2	3	4
Dimensions (M)				
Length	2.00			
Width or Diameter	2.00			
Height (or blank)	1.00			
Volume (CU. M.)	4.000			
Pkg. Dimension (M)				
Length	2.00			
Width or Diameter	2.00			
Height (or blank)	1.00			
Pkg. Vol. (CU. M.)	4.000			
Launch Mass (KG)	200.00			
Accel. Max (G)	.0000100			

Equipment Location Legend

5. Free Flyer (Contact-Name-Orbiting)
6. 28.5 Degree Platform
7. Sun Sync/Polar Platform

Equipment Location	5	6	7
Dimensions (M)			
Length			
Width or Diameter			
Height (or blank)			
Volume (CU. M.)			
Pkg. Dimension (M)			
Length			
Width or Diameter			
Height (or blank)			
Pkg. Vol. (CU. M.)			
Launch Mass (KG)			
Accel. Max (G)			

Attach Points 1

Set Up Code:

Assembly

Hardward Description:

A chamber within an enclosure. The chamber is equipped with several axial and radial ports and windows. Vacuum pumps and cryogenic cooling are provided. Cameras, nephelometers, spectrometers, lasers, and high intensity lighting comprise the monitoring and data acquisition system.

Crew

Task:

Integration of components, checkout, sample preparations.

Period (Days)	7.00
IVA total crewtime (MHR)	5.00
EVA PRODUCTIVE CREW TIME (MHR)	0.00

CI-SKILL-TYPE	1	2	3	4	5	6	7
CI-SKILL-LEVEL							
TASK TRAINABLE	0	0	0	0	0	0	1
TECHNICIAN	0	0	1	0	0	0	0
PROFESSIONAL	0	0	0	0	0	0	0

*DAILY OPERATIONS
TASK:
EXPERIMENT PREPARATION, MONITORING, SAMPLE COLLECTION, CLEANUP.
IVA CREW TIME PER DAY (MHR) 1.00

CD-SKILL-TYPE	1	2	3	4	5	6	7
CD-SKILL-LEVEL							
TASK TRAINABLE	0	0	0	0	0	0	1
TECHNICIAN	0	0	1	0	0	0	0
Professional	0	0	0	0	0	0	0

*Periodic Operations
Task:
Maintenance, Modification of Experiment.
IVA occurrence interval (days) 7.00
Crew time/occurence 1.00
EVA occurrence interval (days) 0.00
Productive crew time/occurrence (MHR) 0.00

CP-SKILL-TYPE	1	2	3	4	5	6	7
CP-SKILL-LEVEL							
Task Trainable	0	0	0	0	0	0	1
Technician	0	0	0	0	1	0	0
Professional	0	0	1	0	0	0	0

*Teardown and Stow
Task:
Stowage of experiments (for return or on-orbit stowage), set up for exp
Period (days) 180
IVA total crewtime (MHR) 5.0
EVA productive crew time (MHR) 0.00

CS-SKILL-TYPE	1	2	3	4	5	6	7
CS-SKILL-LEVEL							
Task Trainable	0	0	0	0	0	0	1
Technician	0	0	0	0	1	0	0
Professional	0	0	0	0	0	0	0

Comments (Crew):
The facility once setup remains for several years with various experiments switched in and out every 90 to 180 days.

Servicing
Interval (Days) 90
Consumables:
Type -
Materials, Film, Videotape
Weight (KG) 2.00
Return (KG) 2.00
Volume Up (Cubic Meters) 1.000
Volume Down (Cubic Meters) 1.000
Power (KW) 0.000
Hours for power 0.00
EVA hours per service 0.00
Typical tasks (EVA) -
IVA hours per service 1.00
Location of servicing Local
Typical tasks (IVA) -
Unpack materials and supplies and stow, pack used mat./records for ret.
Special considerations (servicing):
Sample may be fragile and require special packing for protection.

Configuration changes
Interval (days) 180
Change-out equipment:
Type -
Change out of chamber and monitoring equipment.
Weight (KG) 100.000
Return (KG) 100.00
Volume up (cubic meters) 4.000
Volume down (cubic meters) 4.000
Power (KW) 0.000
Hours for power 0.00
EVA hours per change 3.00
Typical tasks (EVA) -
Remove from orbitor and transfer to station.
IVA hours per change 5.00
Location of change Local
Typical tasks (IVA) -
Remove and pack prior experiment, install new system
Special considerations (config. changes):
These are higly variable, ranging from a change out of materials and sensors (very likely servicing) to a complete change out of the experiment chamber with a different type. Data above refers to the largest case.
Special notes
Contamination-
Dust and particulates are used, as are small quantities of various gases (CO, CO2, H2, CH4, HE, NH3, etc.). Some experiments need very low humidity.
Structures-
Both pressures (1 ATM) and vacuum will need to be maintained for up to 30 days.
Materials-
Particulates and fluids in highly dispersed states will need to be handled.

Radiation-

Some experiments might be influenced: Monitoring of radiation will be needed.

Safety-

Some experiments use low velocity projectiles: Others use gases, and others use high temperatures.

Storage-

Need approximately a single rack for supplies and spares. The various experiments might be stored externally on-orbit rather than returned.

Optical window-

None known.

Scientific airlock-

None known.

Tether-

None known.

Vacuum venting-

Most experiments need a vacuum source (10E-9 ATM). Gases used in some experiments will need to be vented at the termination.

Other-

Some sample and experiment products may be so fragile that on-orbit preparation and analysis will be needed. Fluid handling and storage of ices will be required.

CHAPTER 2

COSMIC DUST COLLECTION

FACILITY

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INTRODUCTION

The term "cosmic dust" is applied to extraterrestrial particles of less than 1 mm in diameter. Observational and theoretical evidence indicates that they are derived predominantly from comets and asteroids, but interstellar grains should also be present. Comets and asteroids are expected to preserve evidence of physical and chemical processes in the early solar system; this information will provide critical boundary conditions for the formation of planets and the evolution of life. Interstellar particles may offer similar information about prestellar nebulae or other evolutionary stages of other solar systems, and may provide critical tests of current astrophysical theories, including those related to nucleosynthesis.

If the capability were emplaced to capture individual particles in near-Earth orbit and to measure simultaneously their trajectories with sufficient precision, their astrophysical sources might be reconstructed. Significant information on a number of primitive parent bodies may be obtained. Direct sampling of these sources via dedicated sample return missions will be limited -- at best -- to a comparatively small number of bodies. The cumulative particle flux of cosmic dust from all sources combined is fairly well established and known to be extremely small. As a consequence, cosmic dust studies in near-Earth orbit require inherently large surface areas combined with long exposure times to detect statistically significant numbers of particles. Under these constraints, the Space Station emerges as a highly suitable platform.

In order to assign to each particle a specific astrophysical source, it is necessary to precisely determine their geocentric orbits. This requirement mandates that the particle collector and trajectory measurement sensors be placed in low Earth orbit. Assignment of astrophysical sources is not possible after severe modification of the initial trajectory by atmospheric drag. For example, particles collected in the atmosphere, deep sea sediments, or antarctic ice cannot be directly associated with their parent objects.

It is therefore proposed to install a Cosmic Dust Collection Facility on Space Station. This facility will incorporate sensors for determining particle trajectories and will deploy capture media to recover the particles in a form suitable for detailed physical, chemical, and isotopic analyses in state-of-the-art, terrestrial laboratories. Deceleration and nondestructive capture of hypervelocity particles, whose specific kinetic energies exceed those needed for melting and vaporization, is a fundamentally difficult task. However, capture of intact fragments seems feasible, and efficient trapping of vapors can also be accomplished. This is the reason why two experimental trapping mechanisms are advocated throughout this report: a) porous, foamy target media for fragment capture at modest impact velocities; and b) efficient trapping and concentration of vapors at high velocities via sequentially stacked foils, known as a "capture cell." Both capture mechanisms may use the same trajectory sensors.

To first order, the cosmic dust flux is isotropic and it follows that a cosmic dust facility must expose surfaces of different viewing directions, preferably scanning the entire sky. Total surface area per viewing direction should be a few square meters. A cube-shaped structure of some 3 x 3 x 3 m can satisfy these and other experimental constraints. Figure 1 illustrates a conceptual, representative design for cosmic dust capture on Space Station.

The cumulative mass-frequency distribution and flux of cosmic dust particles are illustrated in Figure 2. While particles of all masses are of principal interest, current analytical techniques combined with current capture technologies make it desirable to optimize the collector performance for particles approximately 10^{-11}-g and larger. This leads to a few impact events per m^2/year only and it becomes operationally desirable to subdivide the large collector surfaces into arrays of identical, but physically small, subunits. Only a (small) fraction of these subunits, termed Orbital Retrieval Units (ORU), will have to be harvested on occasion for retrieval and analysis of the projectile residue. The harvested subunits would be replaced by pristine collectors. Ideally, the trajectory sensors would be mechanically, electrically, and electronically separated from the capture device, such that only the actual capture medium has to be retrieved.

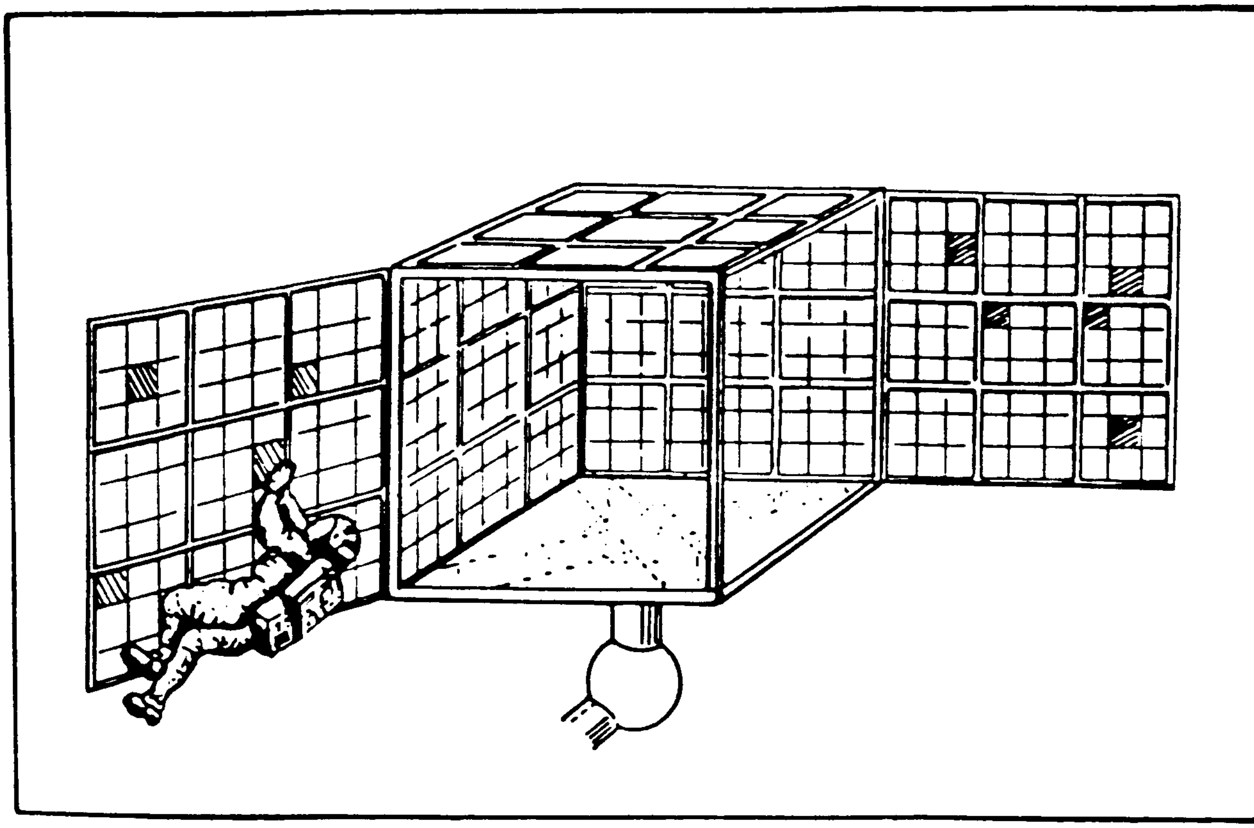

Figure 1: Conceptual sketch of anticipated Cosmic Dust Facility on Space Station. A cubicle structure, approximately 3 x 3 x 3 m, exposes some $9m^2$ in each of 5 viewing directions. These surfaces are subdivided into arrays of smaller subunits that may be removed during periodic EVAs for return to Earth; only those units which actually were impacted will be harvested and replaced with new units. The trajectory sensors must clearly be located in front of the capture devices to determine orbital parameters prior to capture. Anticipating that the trajectory sensors will not be part of the capture units, retrieval of the collectors will have to occur from the rear, the reason why the large cube faces accommodating the detectors are shown to be hinged.

These considerations combine into facility performance requirements that may be summarized as follows: a) some 45 m^2 of total surface area will be exposed and different viewing directions will be necessary; b) these large surface areas will be occupied by arrays of ORUs; c) a fraction of the ORUs will be retrieved at periodic intervals and new units will replace the harvested ones; d) two principal types of ORUs are contemplated, one consisting of porous-foamy capture media, the other of capture cells. Their geometries and design will be such that the 2 types of collectors are interchangeable; e) each detector will be equipped with trajectory sensors that -- ideally -- are not an integral part of the capture device and that will therefore not be

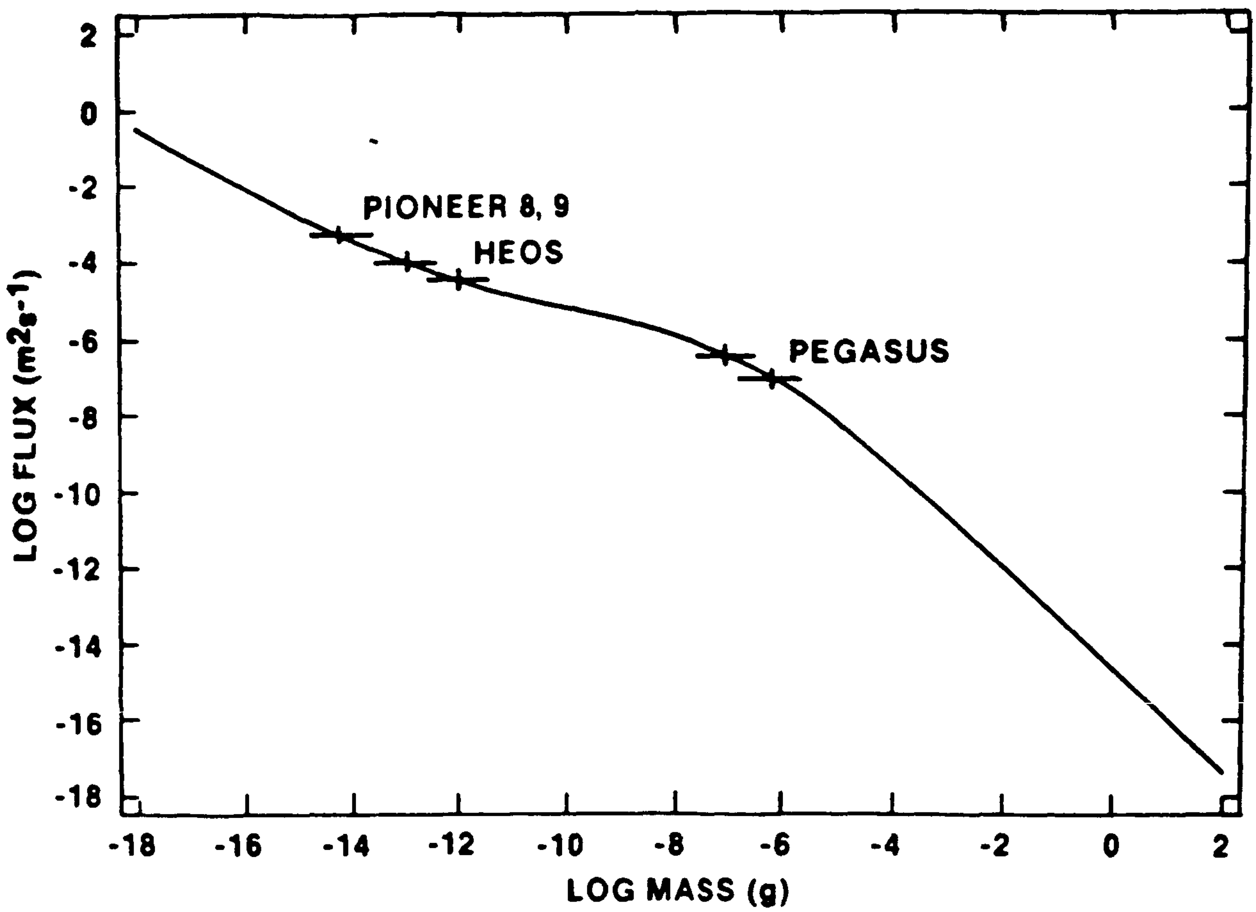

Figure 2: The cumulative mass-frequency distribution and associated flux of micrometeoroids according to the summary of Grun et al. (1985).

harvested and replaced; f) operation of the facility includes EVAs, continued access to power and Space Station navigational data, and the use of STS for transport of retrieval and replacement parts. These requirements necessitate an attached payload class facility for the Space Station that is accessible to qualified researchers and that is sufficiently flexible to accommodate a variety of instrument designs within a standardized envelope established for the ORUs.

RATIONALE FOR EXOBIOLOGY EXPERIMENTS

Cosmic dust, or interplanetary dust particle (IDP), collection requires large collection surfaces and long exposure times that may be achieved with the completion of the Space Station. Collected IDPs could then be studied to learn about formational processes of asteroids and interstellar solices.

IDPs are samples of primitive materials that have recently been liberated from comets and asteroids; a minor fraction originates from the contemporary interstellar medium. The relative contributions of these diverse astrophysical sources are poorly characterized at present, but a statistically significant particle population will contain samples formed under physical and chemical settings unlike those represented by extraterrestrial materials currently available for.analysis. The latter largely reflect processes in the inner solar system, including planet formation, differentiation, and surface evolution.

Laboratory studies on IDPs recovered from the stratosphere have shown that the particles are complex, heterogeneous assemblages of crystalline and amorphous phases that reflect a wide diversity of formational conditions. The elemental, isotopic, and mineralogic characteristics of some particles are consistent with an origin from the same parent bodies that produced the various meteorite classes. Many of the particles, however, are clearly not derived from the solar system objects that spawned fragments large and strong enough to become conventional meteorites.

The components in many IDPs may have originated as stellar or nebular condensates, interstellar dust, and/or interstellar or nebular molecules; they may also be the products of parent-body processes such as the reworking of surface deposits. The study of interplanetary dust collected in the stratosphere or in space enhances the understanding of comets, asteroids, and the early solar system on one hand, and potentially increases knowledge of the interstellar medium on the other. Therefore, general studies of IDPs have high scientific interest for NASA programs in solar system exploration, astronomy, astrophysics, and exobiology; the instrumentation contemplated will also contribute to a better understanding of the nature and evolution of fine-grained orbital debris.

Collection of cosmic dust particles in space provides several unique capabilities in relation to conventional IDPs collected as micrometeorites in the stratosphere. The association of particles with known astrophysical sources requires measurement of the velocity and orbital trajectory elements prior to entry into the Earth's atmosphere. Reconstruction of the source area is possible only via in situ measurements on spacecraft. Moreover, collection in Earth orbit will eliminate any atmospheric selection effects. It is possible that there are classes of volatile-rich or very porous, fragile particles that can be collected only in space.

The great interest in and importance of IDPs to exobiology stems from the potential for contributions toward elucidation of the cosmic history of the biogenic elements that make up all life -- C, H, N, O, P, and S. Three broad scientific issues are encompassed: 1) the chemical and physical phenomena involved in the path taken by these elements from nucleosynthesis to their incorporation as compounds and minerals in primiative solar system bodies; 2) use of biogenic elements in components as probes to elucidate aspects of solar system formation; and 3) properties of these materials that may have influenced processes in the origin and evolution of the solar system.

Current analytical methods and approaches in the investigation of individual dust particles can provide a wealth of information related to the concentration of elements (either bulk or phase chemistry), the identification of molecular species, the characterization of isotopes, the determination of physical properties, and the interpretation of morphologic, textural, and other petrographic observations. The anticipated trajectory information can place these results into their proper astrophysical context(s), a new and in some instances unique aspect of extraterrestrial materials research. While acquisition of samples in Earth orbit without some degradation is difficult to envision at present, a significant fraction of the above information may also be extracted from captured residues. While retrieval of unmelted fragments appears promising and highly desirable, valuable first-order geochemical and isotopic information may still be obtained on a particle-by-particle basis from condensed vapors.

We are thus confident that a dedicated cosmic dust facility on board the Space Station will make substantial contributions toward answering the following questions:

- What relationships exist between comets, asteroids, and interstellar grains?
- Is there diversity among comets?
- Does particle composition correlate with the history of a comet's activity in the inner solar system?
- What fraction of interstellar grains came from carbon-rich stars and what fraction from those rich in oxgyen?
- What fraction of interstellar grains is processed and essentially reformed in the interstellar medium?
- Are cometary solids composed of nebular condensates or presolar grains?
- What is the organic chemistry of cometary and interstellar grains?
- How do the nature, abundance, and distribution of biogenic elements in comets and asteroids impose bounds on apsects of solar system formation?
- How complex is the organic chemistry of the interstellar gas phase?
- How were solid phases fractionated and distributed among the primitive bodies?

EXOBIOLOGY

EX-1. Collect cosmic dust particles in a form suitable for analysis and identify their sources. IDPs represent primitive solar system and interstellar materials containing biogenic elements (C,H,O,N,P,S) and compounds (H_2O, CO_2, and organics). They provide knowledge on the chemical and physical evolution of the solar system and the origin of life.

COSMIC DUST FACILITY

FACILITY DESCRIPTION

Discipline: Planetary Science/Exobiology

Session Title: Cosmic Dust Facility

Objective: Support the collection of cosmic dust grains in a form suitable for chemical, isotopic and physical analysis. Support the determination of individual cosmic dust grain mass, velocity, and travel direction, all of which are used to determine particle origin, i.e., asteroidal, planetary, cometary, or interstellar.

Performance Requirements

1. The facility consists of a frame, which will support 45 trays, each tray measuring 1 m x 1 m and containing 100 "orbital retrieval units" (ORUs, defined elsewhere).

2. Five different viewing directions are required, each occupied by 9 instrument trays, half of which contain foam particle collectors. Viewing directions must include:
   a. Parallel to station velocity vector (leading side)
   b. Anti-parallel to velocity vector (trailing edge)
   c. Perpendicular to velocity vector (right)
   d. Perpendicular to velocity vector (left)
   e. Perpendicular to velocity vector (sky facing).

3. Trajectory sensors will be mounted onto this frame, one directly in front of each ORU.

4. Self-contained electronics are required to process the event data as described in the attachments.

5. A microcomputer will be contained within this frame and connected to each of the trajectory sensors. This computer will monitor the location and time of impacting cosmic dust particles in real time.

Measurements/Samples

The trajectories of incoming particles need to be determined (i.e., velocity measurements and angle of impact between 2 (minimum) planes). Approximately 200 events per 90-day period are expected. The types of measurements obtained, and their processing -- including interface with the Space Station to obtain trajectories in a geocentric reference frame, are described in an attachment.

Sample Analysis (In- or Postflight)

Data concerning each cosmic dust particle collection event will be downlinked to Earth via the Space Station.

Experiment Controls

Not applicable.

Equipment

1. 1 frame to hold individual ORUs, measuring $3m^2$, and weighing 500 kg.

2. 1 microcomputer, 0.2 kW, weighing 10 kg.

3. 2 ORU storage containers, for the storage and transports of ORUs, measuring 1 m x 1 m x 1.2 m, and weighing 25 kg each.

Step Description

See section entitled "Typical 90-Day Collection Scenario," elsewhere.

Experiment Site

Exterior of Space Station, at a position which is subject to the minimum amount of particulate contamination and minimal shielding by other structures. Recommend initial deployment on the cross-beam during Space Stations's early man-tended phase, with the facility being moved to the upper boom when this structure is completed.

PASSIVE COLLECTION VIA FOAM
EXPERIMENT DESCRIPTIONS

Discipline: Exobiology/Planetary Science

Session Title: Cosmic Dust Collector: Passive collection via foamy or otherwise porous (low density) media for nondestructive particle deceleration and capture.

Objective: Collect cosmic dust grains in a form suitable for chemical, isotopic and physical analysis. Determine individual grain mass, velocity, and travel direction, all of which are used to determine particle origin, i.e., asteroidal, planetary, cometary, or interstellar.

Performance Requirements

1. The collector surfaces will consist of approximately 45 instrument trays, each tray measuring 1 m x 1 m. Half of the trays will contain the foam particle collectors.

2. Five different viewing directions are required, each occupied by 9 instrument trays, half of which contain foam particle collectors. Viewing directions must include:
   a. Parallel to station velocity vector (leading side)
   b. Anti-parallel to velocity vector (trailing edge)
   c. Perpendicular to velocity vector (right)
   d. Perpendicular to velocity vector (left)
   e. Perpendicular to velocity vector (sky facing).

3. Each instrument tray will be subdivided into "orbital retrieval units" (ORUs), typically 0.1 m x 0.1 m in surface area; thus, at 100 ORUs per instrument tray there will be 2250 ORUs of the foam collector type. Each ORU will be approximately 1 m deep, to allow for long deceleration paths, and therefore the least destructive particle capture.

4. Each ORU is equipped with a trajectory measurement system, details to be determined, but its dimensions and mass are included in the data/dimensions described elsewhere.

5. Each ORU weighs approximately 200 g and requires approximately 0.2 W DC for continuous operation (totalling 450 kg and 450 W).

6. Self-contained electronics are required to process event data as described in the attachments.

Measurements/Samples

The trajectories of incoming particles need to be determined (i.e., velocity measurements and angle of impact between 2 (minimum) planes). Approximately 200 events per 90-day period are expected. The types of measurements obtained, and their processing -- including interface with the Space Station to obtain trajectories in a geocentric reference frame, are described in an attachment.

Sample Analysis (In- or Postflight)

Approximately 100 of this type of ORU will be changed out every 90 days. No analysis will be performed at the Space Station. All microanalytical characterization will be performed in a terrestrial laboratory.

Experiment Controls

Not applicable.

Equipment

1. 2450 ORUs, each measuring 0.1 m x 0.1 m x 1 m, weighing 200 g. Each ORU consists of a foam capture medium unit with a handle and snap-on device for easy installation/removal. (2250 ORUs in the instrument trays, 100 in the ORU storage container, and 100 ferried back and forth by the Space Shuttle.)

2. 2250 trajectory sensors, each attached to the Cosmic Dust Facility frame, directly in front of one ORU, and weighing approximately 9 g each.

Step Description

See section entitled "Typical 90-Day Collection Scenario," elsewhere.

Experiment Site

See "Cosmic Dust Facility Description."

PASSIVE COLLECTION VIA SEQUENTIALLY STACKED FOILS (CAPTURE CELL) EXPERIMENT DESCRIPTIONS

Discipline: Exobiology

Session Title: Cosmic Dust Collector: Passive collection via sequentially stacked foil surfaces for particle deceleration and capture.

Objective: Collect cosmic dust grains in a form suitable for chemical, isotopic and physical analysis. Determine individual grain mass, velocity, and travel direction, all of which are used to determine particle origin, i.e., asteroidal, planetary, cometary, or interstellar.

Performance Requirements

1. The collector surfaces will consist of approximately 45 instrument trays, each tray measuring 1 m x 1 m. Half of the trays will contain the stacked foil particle collectors.

2. Five different viewing directions are required, each occupied by 9 instrument trays, half of which contain capture cell particle collectors. Viewing directions must include:
   a. Parallel to station velocity vector (leading side)
   b. Anti-parallel to velocity vector (trailing edge)
   c. Perpendicular to velocity vector (right)
   d. Perpendicular to velocity vector (left)
   e. Perpendicular to velocity vector (sky facing).

3. Each instrument tray will be subdivided into "orbital retrieval units" (ORUs), typically 0.1 m x 0.1 m in surface area; thus, at 100 ORUs per instrument tray there will be 2250 ORUs of the foil capture cell particle collector type. Each ORU will be approximately 0.1 m deep.

4. Each ORU is equipped with a trajectory measurement system, details to be determined, but its dimensions and mass are included in the data/dimensions described elsewhere.

5. Each ORU weighs approximately 200 g and requires approximately 0.2 W DC for continuous operation (totalling 450 kg and 450 W).

6. Self-contained electronics are required to process event data as described in the attachments.

Measurements/Samples

The trajectories of incoming particles need to be determined (i.e., velocity measurements and angle of impact between 2 (minimum) planes). Approximately 200 events per 90-day period are expected. The types of measurements obtained, and their processing -- including interface with the Space Station to obtain trajectories in a geocentric reference frame, are described in an attachment.

Sample Analysis (In- or Postflight)

Approximately 100 of this type of ORU will be changed out every 90 days. No analysis will be performed at the Space Station. All microanalytical characterization will be performed in a terrestrial laboratory.

Experiment Controls

Not applicable.

Equipment

1. 2450 ORUs, each measuring 0.1 m x 0.1 m x 1 m, weighing 200 g. Each ORU consists of a foil capture cell unit with a handle and snap-on device for easy installation/removal. (2250 ORUs in the instrument trays, 100 in the ORU storage container, and 100 ferried back and forth by the Space Shuttle.)

2. 2250 trajectory sensors, each attached to the Cosmic Dust Facility frame, directly in front of one ORU, and weighing approximately 9 g each.

Step Description

See section entitled "Typical 90-Day Collection Scenario," elsewhere.

Experiment Site

See "Cosmic Dust Facility Description."

COSMIC DUST COLLECTION FACILITY
ONBOARD PROCESSING

All experiments on the facility will interface through a dedicated computer. When an impact occurs, instrument measurements will be processed by the facility computer and formatted into an "impact event package" that is stored in the main station computer. This data (several event packages) is periodically transferred to the central Space Station computer for transmission to ground. Each "impact event package" will contain processed instrument data that will provide time of impact, velocity of incident particle, position of impact within ORU (thereby which ORU has been impacted) and Space Station data on time, attitude, orbit position, sun vector and orientation. Housekeeping and engineering data from instruments in the facility will also be transmitted to ground on a periodic basis, e.g., once per week. One Mbit of onboard storage is required to store data prior to transfer to the Space Station's central computer and transmission to ground. The generation rate of data from station to ground is equal to or greater than 0.1 Kbps.

Access to an interactive voice link from station to ground, and from ground to station, is required on a irregular, infrequent basis to pass real-time instructions to astronauts, or to receive real-time information from astronauts regarding the facility.

TYPICAL 90-DAY COLLECTION SCENARIO

1. Space Station personnel receive a radio transmission from the ground advising them which ORUs to replace. These are the individual 10 cm x 10 cm (third dimension will be either 10 cm or 100 cm, depending upon type) cosmic dust collection units. In order to minimize work during the Shuttle docking period, we recommend that ORU changeouts be performed just prior to the visit by the Shuttle. The list of ORUs received from the ground will give the location of each ORU to be replaced. There are two types of ORUs: type 1 ORUs measure 0.1 m x 0.1 m x 0.1 m, and are called capture cells; type 2 ORUs measure 0.1 m x 0.1 m x 1 m, and are called foam collectors. Up to 100 of each type of collector will be replaced at this time.

2. 100 of each type of unexposed collector are stowed at the Space Station in an ORU storage container. A worker takes this container, and the list of ORUs to be changed out, to the cosmic dust collection facility.

3. The sides of the collection facility are hinged, allowing access to the inside of the facility as well as the inner surface of each side of the facility. The ORUs are installed into each side of the facility from inside (inner surface). Each ORU has a lever to hold it in place in the facility, and a handle. The worker opens one side of the facility, to expose the back side of all of the ORUs on that side (there are 900 ORUs on each side, arranged into 9 trays each containing 100 ORUs). According to the list of ORUs to be replaced, he removes each designated ORU, and replaces it with an unexposed (pristine) ORU from the ORU storage container. He may replace it with the same type of ORU which he removed, or another type, depending upon his written instructions. He places each old (exposed) ORU into the ORU storage container in place of the ORU he has just removed. He continues in this manner until all of the ORUs on that particular side of the Cosmic Dust Facility have been replaced. He then closes the side (like closing a door) and proceeds to the next side of the facility. He continues in that manner until all designated ORUs have been replaced. As each old (exposed) ORU is placed into the storage container, it is labeled on the back with the coordinates of the ORU, so

that on Earth its position within the Cosmic Dust Facility may be determined.

4. When finished, the worker has closed all sides of the cosmic dust facility, and closed the door of the ORU storage container. Allowing 1 minute per ORU changeout, elapsed time is approximately 4 hours. The worker has never touched the front surface of the Cosmic Dust Facility, nor the front surface of any of the ORUs.

5. The worker returns the ORU storage container to its storage position.

6. The Cosmic Dust Facility passively collects cosmic dust particles and measures their trajectories 24 hours a day, for the entire 90-day period between ORU changeout. This occurs in the following manner. As each cosmic dust grain encounters the facility, it first penetrates the trajectory sensor grid, which is arrayed in front of all exposed sides of the facility. The onboard microcomputer senses the location and time of particle penetration. From this data, the microcomputer computes the particle velocity and travel direction. This data is periodically transmitted to the Space Station computer, and then transmitted to a ground-based laboratory (approximately once per week). Meanwhile, the particle continues through the detection grid, and into one or more ORUs, where it is decelerated and stopped. PIs on the ground use the downloaded data from the Space Station to determine in which ORU(s) the particle resides. A list of ORUs to be replaced is compiled from this information, and this list is transmitted to the Space Station personnel just prior to each scheduled ORU changeout operation.

7. In a ground-based clean room new (pristine) ORUs are loaded into an ORU storage container, not to be reopened prior to ORU changeout at the Space Station. This ORU storage container is then loaded onto the next Space Shuttle for shipment to the Space Station.

8. When the Shuttle docks at the Space Station, a worker removes a new ORU storage container (containing pristine ORUs) from the Shuttle cargo bay, and stows the old storage container (containing exposed ORUs) in its

place. The worker then stores the new ORU storage container at the Space Station in preparation for the next ORU changeout, which will occur in approximately 90 days, i.e., just prior to the next Shuttle visit to the Space Station.

9. Upon return of the old ORU storage container to a ground-based clean room facility, exposed ORUs are removed for examination. Captured cosmic dust grains will be removed from the exposed ORUs, and subjected to extensive characterization.

REFERENCE PAYLOAD FOR COSMIC DUST COLLECTOR

EQUIPMENT NAME	QUANTITY	VOLUME	MASS	POWER	DEPTH	WIDTH	HEIGHT	STOWAGE VOLUME
- Frame, to hold ORUs	1	27 m^3	500 kg	0	3 m	3 m	3 m	N/A
- ORU storage container * one needs unpressurized storage space at the Space Station	2*	1.2 m^3	50 kg	0	1.2 m	1 m	1 m	1.2 m^3
- Microcomputer (located within collector frame)	1	0.05m^3	10 kg	0.2 kw	0.1 m	0.1 m	0.5 m	N/A
- Foam collectors ORUs	2450**	0.01 m^3 each	0.2 kg each	0	1 m	0.1 m	0.1 m	N/A
- Capture cell collector ORUs	2450**	0.001 m^3 each	0.2 kg each	0	0.1 m	0.1 m	0.1 m	N/A
** includes 2250 in the collection at any given time, 100 in the ORU storage container, and 100 ferried back and forth by the Space Shuttle.								
- Trajectory sensors	4500	approx. 1 m^3 total***	40 kg	1 kw	***			
*** This is an outer frame which wraps around the ORU frame itself, but which does not add significantly to the overall outside dimensions of the cosmic dust collection facility.								

ORU = orbital replacement unit, i.e., each individual collector unit.

Need two containers -- one for storage, one for Shuttle, to be changed when Shuttle is not there.

MISSION REQUIREMENTS DATA BASE

SAAX112

****
Entries in this data base are to be used only as a source of illustrative detail about the intended uses of the Space Station complex. The data base by itself cannot be used to infer an aggregate performance envelope.
****

NAME

Payload element name	Cosmic Dust Collection Experiment
Last update	082886
Country of origin	USA NASA OSSA (SAAX)
Contact	L. Chambers, Code EB, NASA HQ J. Campbell, Code EL, NASA HQ
Phone number	(202) 453-1525/1608
Status	Planned

FLIGHTS

Flight Schedule

Flight Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
Equipment up	1	0	0	0	0	0	0	0	0	0
Equipment down	0	0	0	0	0	0	0	0	0	0
Operational days	180	365	365	365	365	365	365	365	365	365
OTV flights	0	0	0	0	0	0	0	0	0	0
Early flights	0	0	0	0	0	0	0	0	0	0
Late return										

Objective

Determine the nature, abundance, distribution and physical and chemical characteristics of interplanetary dust by retrieving such particles, accompanied by precise information on the trajectory of the impacting particle.

Description

The experiment is more accurately characterized as a facility for the collection and retrieval of extraterrestrial material and for the measurement of the orbital parameters associated with the material. It is a modular system on which various types of collectors and detectors can be mounted. The system is composed of unit modules (1m x 1m), 9 of which occupy each of the 5 faces of a cubical structure. Both passive and electronically active arrays are planned. Power and data buses are part of the structure. Collection is in cells located behind the arrays. Modules may be up to 1 m deep. Self-contained electronics collect data on impact (time, direction, and velocity). This data combined with data on station orientation, position, and time is periodically telemetered to ground. Individual cells that have been impacted will be routinely replaced at 90-day intervals. Impacted cells will be returned to Earth for chemical, physical and petrographic analysis.

Type/Scale

Type number	2
Importance of Space Station	10
Non-servicing OMV flights (per year)	0
Add resources	Yes
Resource reference	

Orbit

Any orbit

Special considerations (orbit):
Require ancillary data from station concerning attitude

Pointing/orientation

Hours	-0
Truth sites	
Pointing accuracy (arc sec)	-0.00
Pointing knowledge (arc sec)	-0.00
Field of view (deg)	-0.0
Pointing stability rate (arc sec/sec)	-0.000
Pointing stability (arc sec)	-0.000
Placement (arc sec)	-0.000

Special consideration (pointing/orientation)
Require ancillary data from station concerning attitude/orientation.
SS upper boom-end corner location required.

Power

DC

Operating (KW) -- nominal	1.20
Hours per day (orbiting)	24.00
Voltage -- nominal	28.00
Peak (KW) -- nominal	1.20
Hours per day (peak)	24.00
Standby power (KW) (Non-operational periods)	0.00

Special considerations (power):

Thermal

*Active

Temperature, deg C	Operational	Min	-10.00	Max	40.00
	Non-operational	Min	-0.00	Max	-0.00
Heat rejection, KW	Operational	Min	1.20	Max	1.20
	Non-operational	Min	-0.00	Max	-0.00

Special considerations (thermal):
Thermal control is integral to experiment

Data/Communications

Onboard data processing required Yes

Description:
Enginering, housekeeping, analysis

Onboard storage (Mbit) 1.00

Station data required:
Time/attitude/orbit position/sun vector/orientation

Communication links:

FROM: STATION TO: GROUND	DIGITAL DATA	VIDEO DATA	VOICE
a. Generation rate (Kbps)	0.10	-0.00	NA
b. Duration (hours)	1.00	-0.00	-0.00
c. Frequency (per day)	1.00	-0.00	-0.00
d. Delivery time (hours)	-0.00	-0.00	0.00
e. Security (yes/no)	no		
f. Reliability (%)	0.00	-0.00	-0.00
g. Interactive (yes/no)	no		yes

FROM: GROUND TO: STATION	DIGITAL DATA	VIDEO DATA	VOICE
a. Generation rate (Kbps)	0.10	-0.00	NA
b. Duration (hours)	0.50	-0.00	-0.00
c. Frequency (per day)	1.00	-0.00	-0.00
d. Delivery time (hours)	-0.00	-0.00	0.0
e. Security (yes/no)	no		
f. Reliability (%)	50.00	-0.00	-0.00
g. Interactive (yes/no)	yes		yes

Comment (data/communication):
Experiment generated data (impact occurrence, velocity, relative trajectory) must be correlated with station position, velocity, and orientation to yield particle trajectory.

Equipment
Pressurized module code 1
Shared facilities None
Equipment location legend
1. Internal/pressurized
2. External/attached/unpressurized
3. External/attached/pressurized
4. Free-flyer (remote)

	EQUIPMENT LOCATION 1	2	3	4
Dimensions (m)				
Length			3.00	
Width or diameter			3.00	
Height (or blank)			3.00	
Volume (cu. m.)			27.000	
Pkg. dimension (m)				
Length			3.00	
Width or diameter			3.00	
Height (or blank)			1.00	
Pkg. vol. (cu. m.)			9.000	
Launch mass (Kg)			1600.00	
Accel. Max (G)				

Equipment location legend
5. Free-flyer (contact-name-orbiting)
6. 28.5 degree platform
7. Sun sync/polar platform

	EQUIPMENT LOCATION 5	6	7
Dimensions (m)			
Length			
Width or diameter			
Height (or blank)			
Volume (cu. m.)			
Pkg. dimension (m)			
Length			
Width or diameter			
Height (or blank)			
Pkg. vol. (cu. m.)			
Launch mass (Kg)			
Accel. Max (G)			
Attach points		1 Deployment assembly	

Hardware description:
System is a 3m x 3m cubical structure, 5 sides of which have 9 1m x 1m compartments. Attachment is provided from the sixth side. Sides are hinged to provide access to service experiments which are housed in the compartments. Data, power buses, electronics are inside the structure.

ew

*Initial construction/set up

Task:

Deployment and assembly

Period (days)	2.00
IVA total crew time (MHR)	0.50
EVA productive crew time (MHR)	28.00

CI-SKILL-TYPE	1	2	3	4	5	6	7
CI-SKILL-LEVEL:							
Task trainable	1	0	0	0	0	0	0
Technician	1	0	0	0	0	0	0
Professional	0	0	0	0	0	0	0

*Daily operations

Task:

Verify system operations

IVA crew time per day (MHR)	0.20

CD-SKILL-TYPE	1	2	3	4	5	6	7
CD-SKILL-LEVEL:							
Task trainable	1	0	0	0	0	0	0
Technician	0	0	0	0	0	0	0
Professional	0	0	0	0	0	0	0

*Periodic operations

Task:
Change out of test panels

IVA occurrence interval (days)	90.00
Crew time/occurrence	0.20
EVA occurrence interval (days)	90.00
Productive crew time/occurrence (MHR)	4.00

CP-SKILL-TYPE	1	2	3	4	5	6	7
CP-SKILL-LEVEL:							
Task trainable	1	0	0	0	0	0	0
Technician	1	0	0	0	0	0	0
Professional	0	0	0	0	0	0	0

*Teardown and stow
Comments (Crew):

Servicing

Interval (Days) 90

Consumables:

Type -
Test panels (Approx. 150 panels)

Weight (KG)	160.00
Return (KG)	160.00
Volume up (cubic meters)	2.000
Volume down (cubic meters)	2.000
Power (KW)	-0.000
Hours for power	-0.000
EVA hours per service	6.00

Typical tasks (EVA) -
Remove existing panels, replace with new one, and package/unpackage.

IVA hours per service -0.00

Typical tasks (IVA) -

Special considerations (servicing):
Panel may be delicate and sensitive to contamination. Although special containers may be provided handling must be consistent with that of a class 1000 clean room (external requirements). Panels should be removed/replaced from the back side of each particular side of the facility.

Configuration changes None

Special considerations (config. changes):

Special Notes

Contamination -
Possible sensitivity to vapors and particulates. Isolation of collector panel is planned as part of the experiment.

Structures -
None identified. Yet.

Materials -
None identified. Yet.

Radiation -
None identified. Yet.

Safety -
None identified. Yet.

Storage -
Possible spares and electronics. Quantity, size and nature TBD.

Optical window -

None identified.

Scientific airlock -

None identified. Yet.

Tether -

None identified. Yet.

Vacuum venting -

None identified.

Other -

The experiment should be located at that position on the station which has the cleanest environment (particulates and vapor minimized). Impact events occur in random intervals, but can be predicted with great accuracy a few years in advance. Should be no problem.

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REFERENCES

1. Microgravity Particle Research on Space Station. Report of a workshop held at NASA Ames Research Center, 22-24 August, 1985. Edited by Steven A. Squyres, et al.

2. Trajectory Determinations and Collection of Micrometeorites on the Space Station. Report of the Workshop on Micrometeorite Capture Experiments held at the Lunar and Planetary Institute, Houston, Texas. December 16-18, 1985. LPI Technical Report No. 86-05.

3. Exobiology in Earth Orbit. Results of science workshops held at NASA Ames Research Center, August, 1984 and April, 1985. Edited by Douglas J. DeFrees, et al.

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16. Abstract

The Cosmic Dust Collection and Gas Grain Simulation Facilities represent collaborative efforts between the Life Sciences and Solar System Exploration Divisions designed to strengthen a natural Exobiology/Planetary Sciences connection. The Cosmic Dust Collection Facility is a Planetary Science facility, with Exobiology a primary user. Conversely, the Gas Grain Facility is an Exobiology facility, with Planetary Science a primary user.

Requirements for the construction and operation of the two facilities, contained herein, were developed through joint workshops between the two disciplines, as were representative experiments comprising the reference payloads. In the case of the Gas Grain Simulation Facility, the Astrophysics Division is an additional potential user, having participated in the workshop to select experiments and define requirements.

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